NASA SP-5044

TECHNOLOGY UTILIZATION REPORT

Technology Utilization Division

SELECTED CASTING TECHNIQUES

Prepared under contract for NASA
by Philco Corporation,
TechRep Division,
Ft. Washington, Pennsylvania

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

NASA SP-5044

TECHNOLOGY UTILIZATION REPORT

Technology Utilization Division

SELECTED CASTING TECHNIQUES

NATIONAL AERONAUTICS AND SPACE ADMINISTRATION

Washington, D.C. April 1965

For sale by the Clearinghouse for Federal Scientific and Technical Information
Springfield, Virginia 22151 – Price $1.00

CONTENTS

FOREWORD

The Administrator of the National Aeronautics and Space Administration has established a technological utilization program for "the rapid dissemination of information . . . on technological developments . . . which appear to be useful for general industrial application." From a variety of sources, including NASA Research Centers and NASA contractors, space-related technology is collected and screened; and that which has potential industrial use is made generally available. Information from the Nation's space program is thus made available to American industry, including the latest developments in materials, processes, techniques, management systems, and analytical and design procedures.

In accelerated aerospace research programs, aircraft designs must be evaluated rapidly and accurately; therefore, research personnel require wind-tunnel models which can be quickly fabricated regardless of configuration, and to a degree of accuracy commensurate with predetermined specifications. The successful production of a wind-tunnel model, quickly and accurately, depends upon the ingenuity, skill, and experience of the craftsman in the utilization of materials, and the application or modification of established procedures.

Each new model usually involves an entirely new design concept and purpose, or modification of a design currently undergoing evaluation. Therefore, the technical problems associated with the construction of new models are often many and varied. It is for this reason that the craftsmen at NASA Langley Research Center do not adhere to a set or stereotyped method of model construction. However, this publication outlines one method of model construction that incorporates an interesting casting and plasticizing technique developed by Langley Research Center personnel. Although the basic construction processes are not entirely new, the application of material, modification of established or commonly known procedures, and use as an integrated whole are considered unique. In utilizing this method, wind-tunnel models of both simple and complex configuration can be produced rapidly and at reduced cost.

The procedures described in this publication are intended not only to illustrate the construction of a wind-tunnel model, but also to describe and illustrate a casting and plasticizing technique that may be applied to the production, in limited quantities, of simple or complex items not necessarily related to the aircraft industry. The fact that these procedures were developed for the expeditious production of wind-tunnel models does not prevent their application or adaptation, either in whole or in part, to other projects by industry.

SECTION I

CONSTRUCTION OF PATTERN AND FIBERGLASS MOLD

PREPARATION OF TEMPLATES

When the design of the model is finalized, the stations and ordinates for selected sections of the model are developed and tabulated. In order to expedite production of the model, the stations and ordinates of the wing sections are developed in accordance with the reference plane or streamline of the model. Since the fuselage and wing fillet sections are of relatively similar contours throughout the length of the model, the applicable stations and ordinates are developed cross-sectionally. Male templates for the various sections of the model are then lofted by the patternmaker and cut from aluminum plate.

In addition to the foregoing method of fabricating male templates, a second method is, at times, utilized at Langley. In this method, engineering personnel loft the required templates and draw them to oversize scale. The template drawings are then reproduced photographically to a reduced final size on photosensitive aluminum plate. The patternmaker then cuts the templates directly from the aluminum plate. It should be noted, however, that the degree of accuracy depends upon materials and equipment (drafting and photographic) employed in this method.

The use of male templates appreciably decreases the amount of time required to construct the pattern because (1) they present the patternmaker or modelmaker with a true image of the various contours of the model, and (2) by incorporating the templates directly in the pattern, the pattern is quickly and accurately faired to correct contours and dimensions. Male templates also eliminate the slow and tedious fairing process required in the use of female templates.

In the case of those models requiring accuracy as well as speed in construction, female templates (see figure 1) are also prepared. The female templates are used to "spot-check" the contours of the pattern during the fairing process. To make sure that the female templates conform to the exact contours of the male templates, the following method is used:

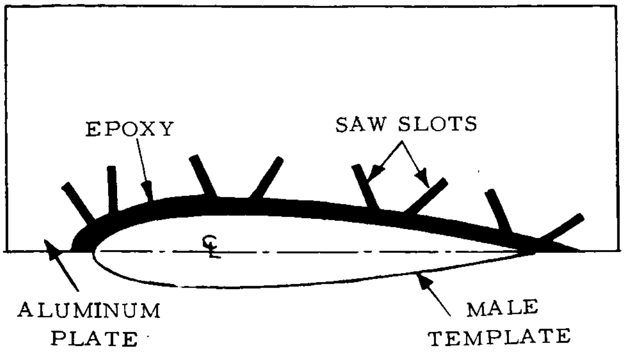


Figure 1. Preparation of Female Templates

1. A section of aluminum plate is cut to the general contour of the upper half of the male template (accuracy in this step is not required).

2. Saw cuts are made in the plate at an angle to, and radiating from, the template outline.

3. The edge of the male template is waxed to form a parting; then the male template is placed in position as shown.

4. The space between the male template and the aluminum plate is filled with a heavy-bodied epoxy, which is then swept, or leveled, and allowed to harden. If required, the lower half of the female template is made in the same manner.

The process just described not only produces female templates that conform exactly to their male counterparts, but also eliminates the time-consuming hand filing and/or sanding process ordinarily required to fair or shape female templates.

After lofting the required templates, the patternmaker incorporates feet at the bottom of selected templates (see figures 2 and 3). The number of templates requiring feet is determined by the patternmaker and is predicated upon the size and complexity of the model. The height of each set of feet is calculated from, and placed in relation to, the reference plane of the model. The addition of feet to the templates is essential, since this is the only method whereby the templates can be kept in true relation to the base line and ordinates of the model.

CONSTRUCTION OF PATTERN

After the templates are completed, mahogany spacer blocks are cut to rough shape in accordance with the basic contours of the model. A plan form of the model, with applicable stations and ordinates, is laid out on a surface table. The templates and spacers are then assembled and glued together in true relation to the station ordinates and reference plane. Figure 2 shows a typical assembly of spacer blocks and templates. Although this figure shows the wing and fuselage spacers as cross sections, the actual wing panels of the model discussed in this publication were assembled in accordance with the streamline or chord of the airfoil (see figure 3); the fuselage was assembled by cross sections.

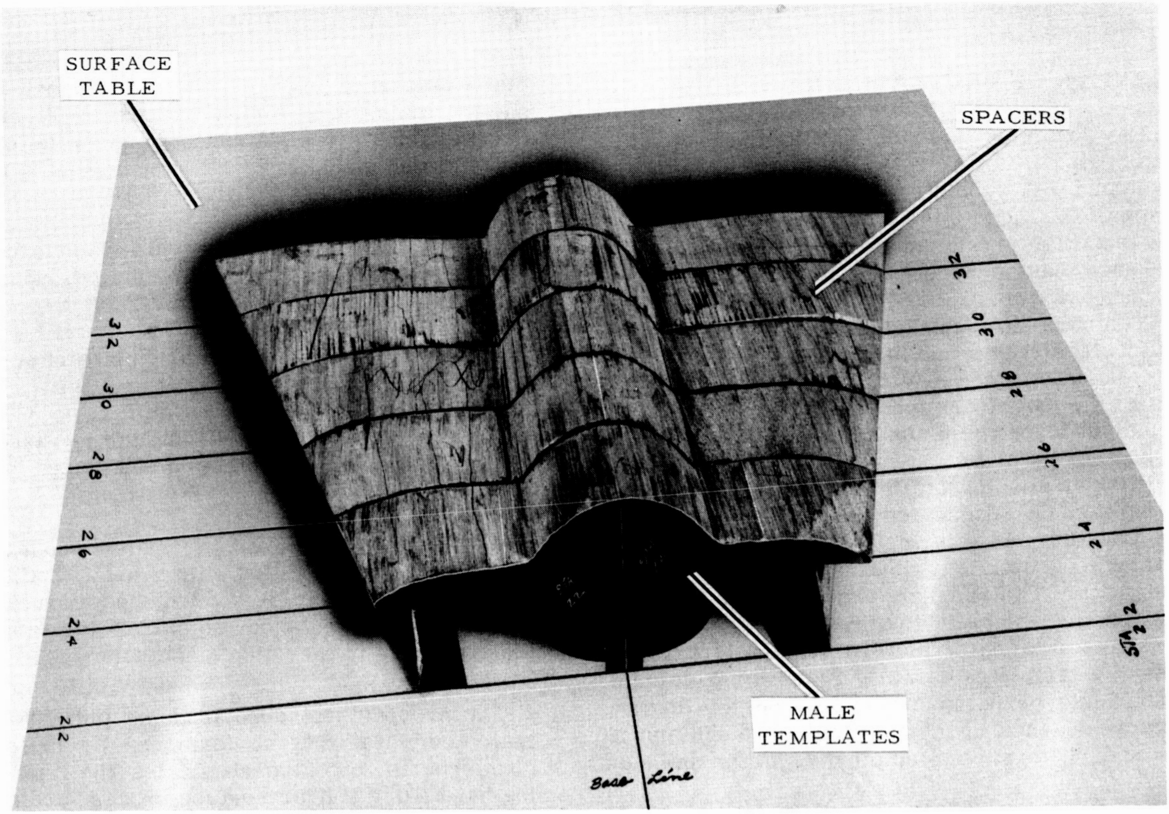


Figure 2. Typical Assembly of Spacer Blocks and Templates

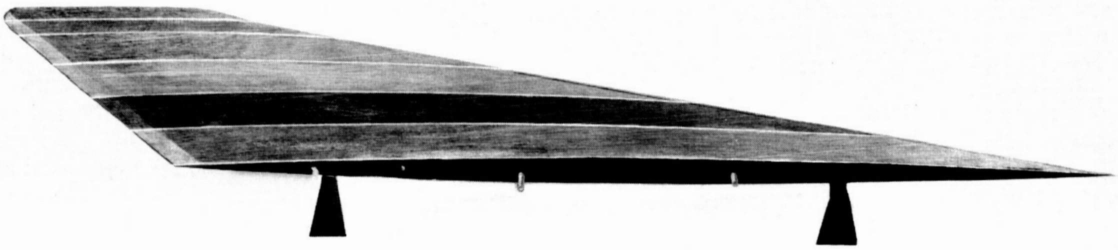


Figure 3. Method of Constructing Wing Sections

After assembly of the spacers and templates, the upper half of the pattern is faired to finished contours and dimensions, using regular patternmaking procedures. When the upper half is finished, clear lacquer is applied as a sealer.

CONSTRUCTION OF FIBERGLASS MOLD

When the construction procedures for the model were discussed, two prime factors were considered: a gun metal casting had to be made, and the metal casting had to be coated with plastic to bring the model to final, precise contours and dimensions. It was decided that a fiberglass mold be constructed and utilized to perform three functions: (1) to serve as a firm base for the pattern when fairing the lower half, (2) to serve as a follow board when preparing the sand mold for the gun metal casting, and (3) to serve as a mold for plasticizing the finished casting. The fiberglass mold, which consists of two parts (upper and lower), is constructed in the following manner (see figure 4):

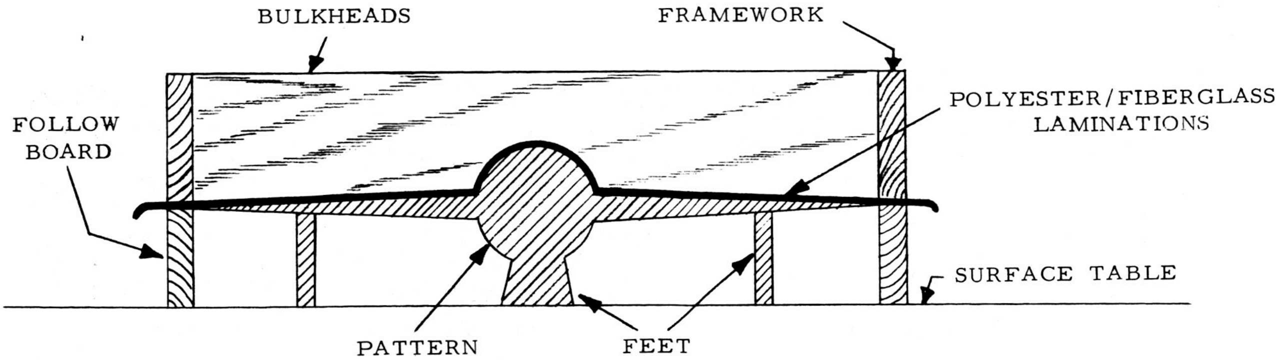


Figure 4. Construction of Fiberglass Mold

1. To form a good parting surface, a coating of wax is applied to the finished, upper half of the pattern. Next, a coating of polyvinyl alcohol is applied, followed by a coating of polyvinyl parting agent.

2. With the pattern securely in place on the surface table, a follow board is fabricated and positioned around the plan form of the model to form a parting for the mold.

3. A gel coat of polyester is then applied to the pattern surface and allowed to dry until tacky. A sheet of fiberglass (0.004-in.-thick) is carefully laid over, and formed to, the upper surface of the pattern. A second gel coat of polyester is applied to the fiberglass, followed by a second sheet of fiberglass (0.015-in.-thick). The fiberglass laminations are built up in the foregoing manner until the mold attains a thickness of approximately 1/8 in.

4. Wood framework and bulkheads are prepared by rough sawing and then potted securely in place (over the fiberglass mold) with gelled polyester (see figure 5). The top of the wood frame and bulkheads is then milled parallel to the reference plane of the model.

5. The finished upper half of the mold is then turned over, forming a rigid support for the pattern. The lower half of the pattern is faired to finished contours and dimensions and sealed with lacquer. Upon completion of the lower half of the pattern (figure 6), the

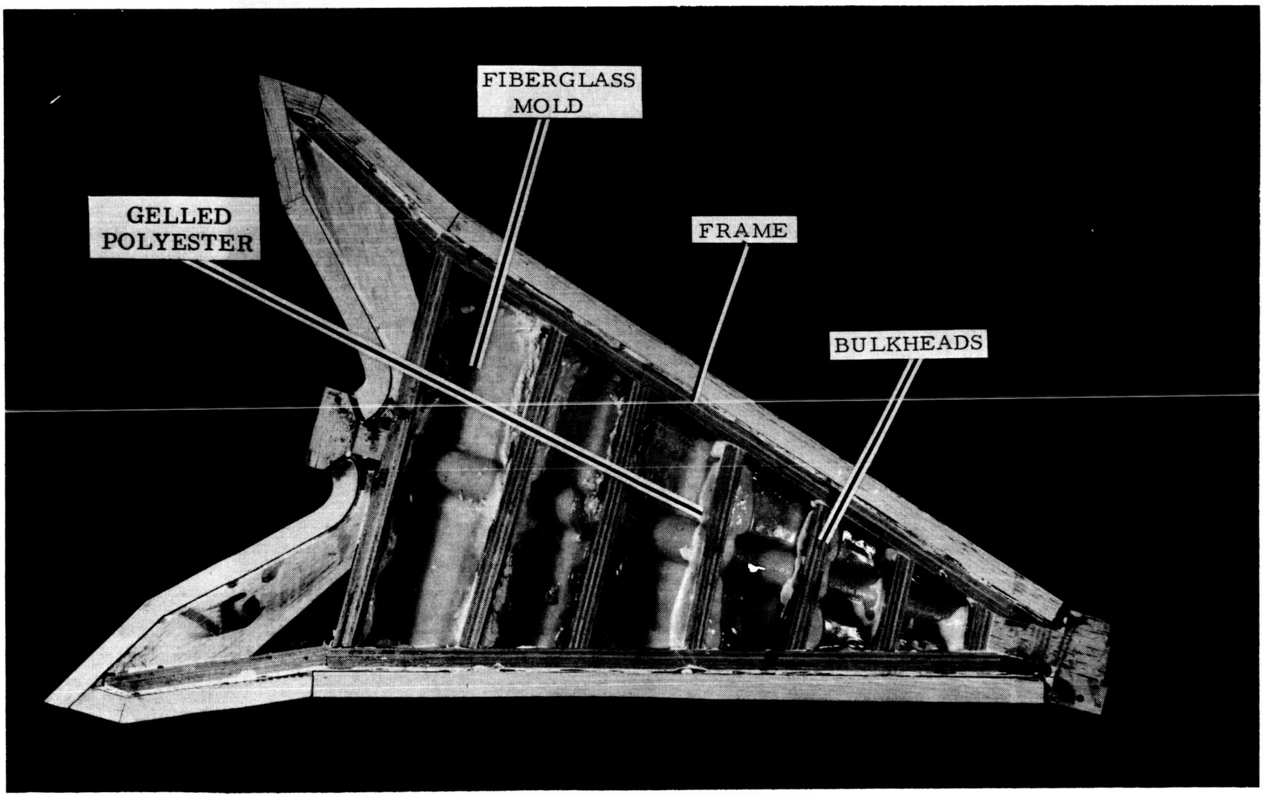


Figure 5. Fiberglass Mold, Showing Framework and Bulkheads

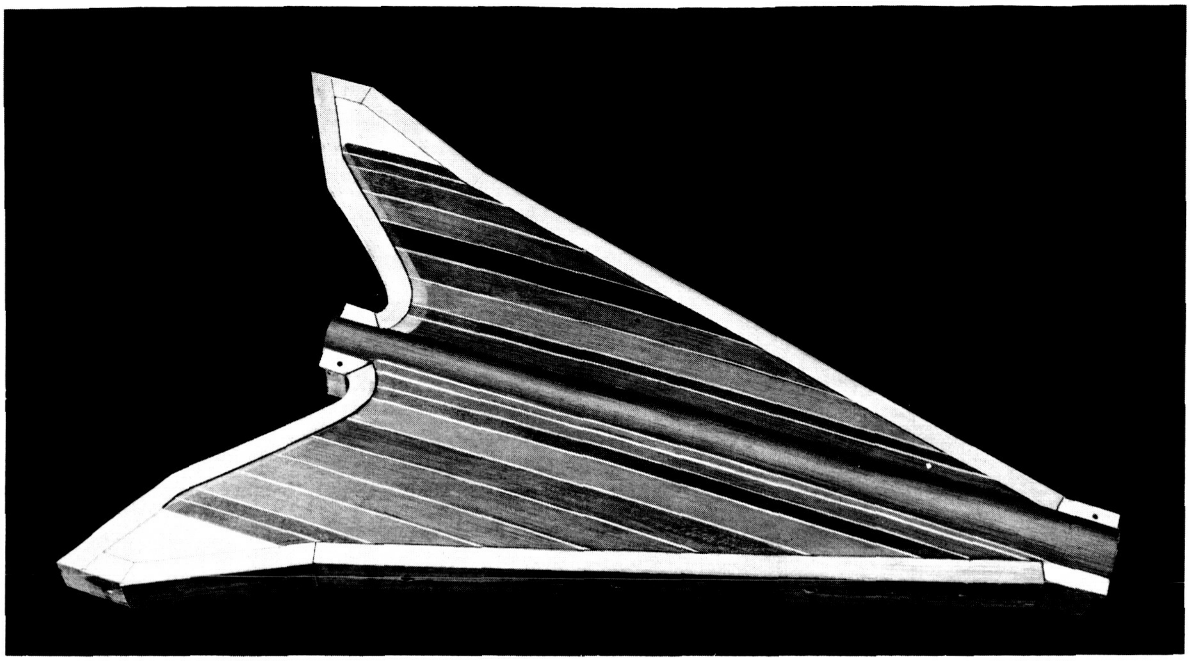


Figure 6. Upper Half of Mold with Pattern in Place

second or lower half of the mold is constructed, utilizing the same process as that for the first or upper half except that the follow board is not required.

6. After both halves of the mold are completed, excess fiberglass is carefully trimmed from the parting.

PREPARATION OF CORE

This model-construction technique has employed the casting of the internal strain-gage balance seat directly into the model. A wind-tunnel model balance is a delicate, force-measuring instrument; therefore, the mating of the balance to the model requires accuracy. The innovation of casting the balance seat serves to decrease the number of operations that are ordinarily required to produce a wind-tunnel model of this type. By casting the balance seat, the necessity for machine boring, drilling, and milling of the casting is eliminated. Since the balance seat is an integral part of the fuselage, a core must be prepared. This is accomplished as follows:

1. A balance seat chill (figure 7) containing the balance seat mounting-bolt holes and two centering-pin holes, is accurately machined to a duplicate of

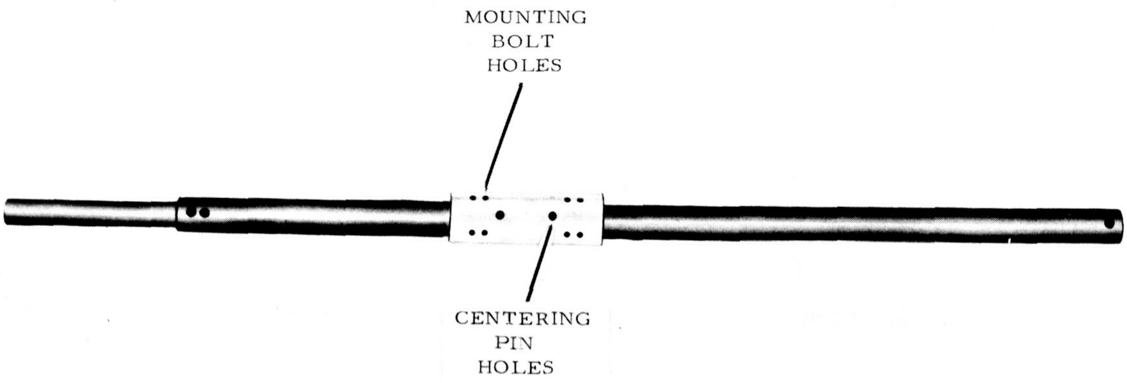


Figure 7. Steel Arbor, Showing Balance Seat Chill

the wind-tunnel balance mounting surface. The chill is drilled and tapped at each end to accept threaded steel rods.

NOTE: The length of the steel rods is determined by the length of the fuselage plus space for the core prints; the axial configuration of the rods is determined by the shape of the fuselage longitudinal center line.

2. Steel balance-seat chill pins are machined as shown in figure 8. These pins determine the location and size of the balance seat mounting-bolt holes in the casting. The chill pins are machined with a 1° taper to permit easy withdrawal from the casting.

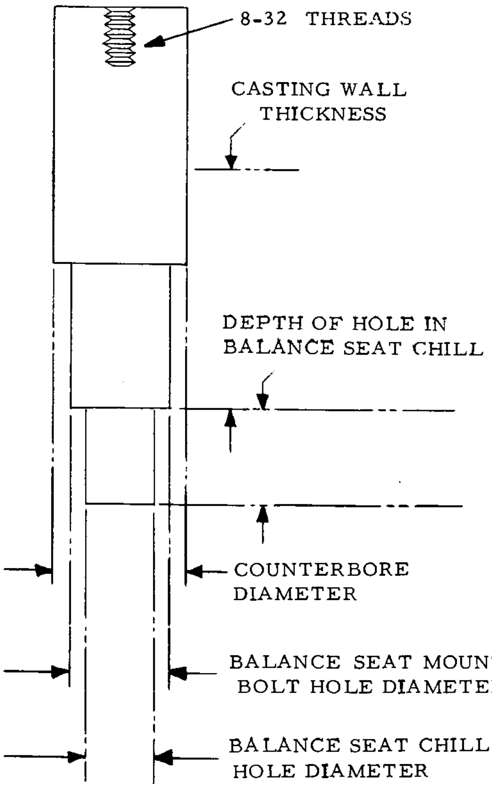


Figure 8. Balance-Seat Chill Pins

3. The location of the balance seat in the casting is determined by the accurate positioning of the centering-pin holes in the pattern. The holes are located on the pattern in accordance with the engineering specifications for the model. The hole centers are measured from zero, or the reference line at the forward extremity of the model. The holes are then carefully drilled in the pattern to a depth corresponding to the wall thickness of the fuselage, plus the depth of the centering-pin holes in the balance-seat chill. The balance-seat bolt-hole centers are also noted on the pattern, but are not drilled.

4. The core box is constructed in two sections, with the parting in accordance with the vertical axis of the fuselage center line.

5. In order to accurately position the steel arbor in the core box, a steel plate is prepared and secured to one half of the core box as shown in figure 9. The two machine screws in the steel plate are located in the same relative position as the centering holes in the balance-seat chill, and are lined up in exact relation to the centering-pin locations. Two fiberboard circular disks are cut to the inside diameter of the core box and the outside diameter of the steel rods. The disks, which are then placed (one each) over the ends of the steel rods, aid in the accurate positioning of the steel arbor in the core box.

6. The steel arbor is placed in the core box and accurately positioned by inserting centering pins in the centering holes in the balance-seat chill. A vent wire (approximately 1/8-in. dia) is positioned along the length of the arbor. (The wire is withdrawn from the core box after the core has been rammed.) The core box is then closed and clamped. Next, the two machine screws are tightened to exert pressure on the centering pins, which, in turn, firmly seat the balance-seat chill against the core-box wall.

7. Wood blocks (figure 10) are prepared and secured to the pattern with double-acting tape over the areas where the balance-seat mounting-bolt holes will appear in the casting. The wood blocks provide space in the sand mold to accommodate the mounting-bolt hole chill pins inserted in the balance seat chill.

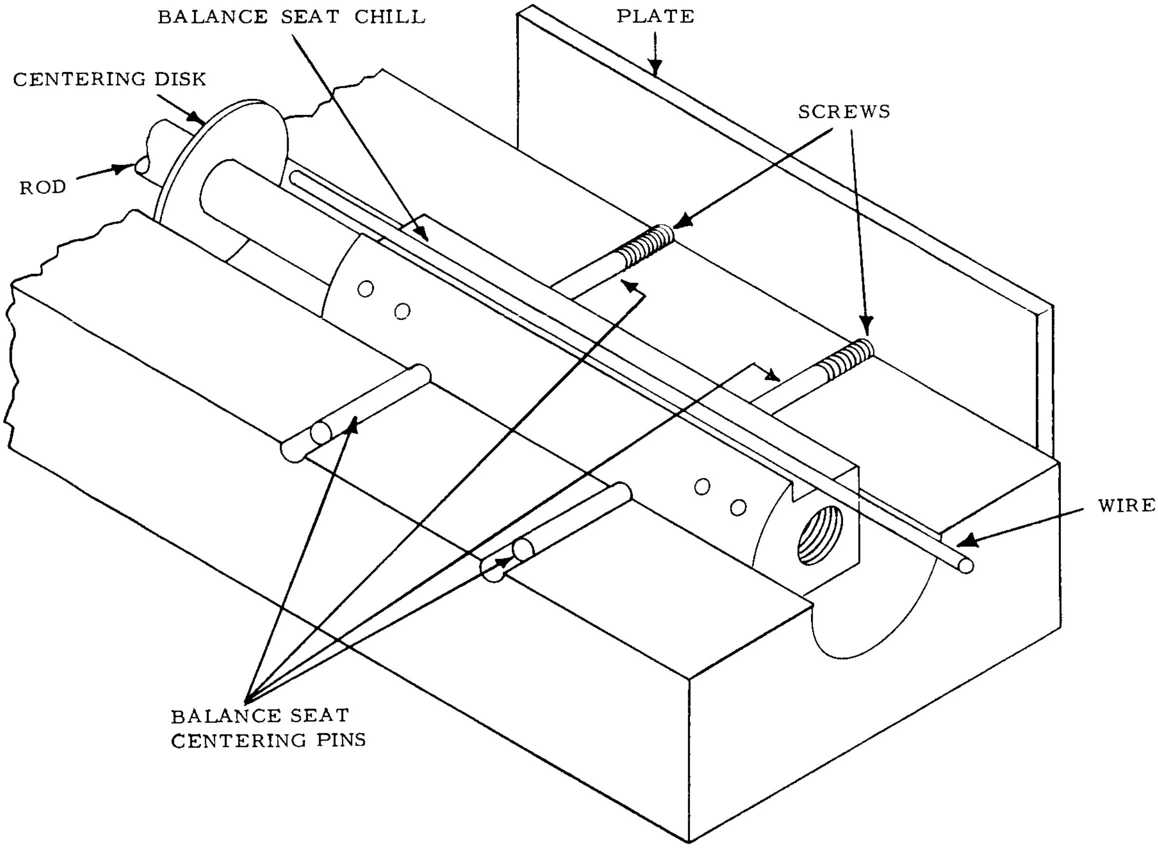


Figure 9. Positioning Balance Seat Chill in Core Box

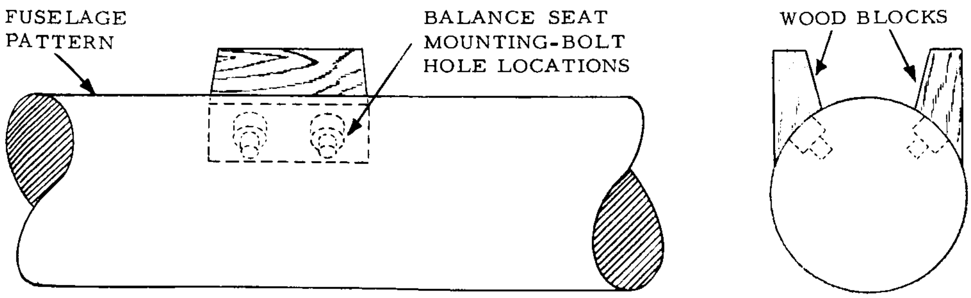


Figure 10. Location of Wood Blocks on Pattern

SECTION II

PREPARATION OF CASTING

PREPARATION OF SAND MOLD

The fiberglass mold, in addition to its ultimate use in plasticizing the model, is also intended to serve as a follow board (support for the pattern) during the preparation of the sand mold. This is an essential step because the airfoil sections of the pattern are quite thin and the rigid support rendered by the mold prevents breakage or warping of the pattern when the sand mold is rammed. The drag, or lower half of the sand mold is prepared as follows:

1. Construction of False Cope. The upper half of the fiberglass mold is placed on a flat bottom board (figure 11). A wood frame, of approximately the same dimensions as the molding flasks and the same height as the fiberglass mold, is secured to the edges of the bottom board. Next, green sand (sand that is bonded, mixed, and tempered with water) is rammed around the fiberglass mold to form the parting line or molding surface of the false cope.

2. Construction of Drag. A suitable molding flask is placed over the false cope. Then, with the pattern in place, wood gates are positioned on the mold parting line. CO_2 process sand (made by mixing a good grade of 60-mesh fresh water sand in a mixer or muller with 4 percent sodium silicate) is rammed over the surface of the false cope to a depth of about 2 in. The remaining space is filled with dry coke which is then covered with CO_2 process sand, rammed, and struck off level with the upper edges of the flask. The CO_2 sand is then cured by impregnation with CO_2 gas (approximately 20 to 30 psi). To facilitate the curing procedure, a small hole (approximately 1/4-in.-dia) is punched through the top layer of sand. The CO_2 gas is introduced into the mold through the hole for a period of about 4 to 5 minutes. After the mold has been cured, it is covered with another bottom board; then the entire assembly (false cope and drag) is clamped together and turned over. The false cope is removed and discarded (after removing the fiberglass mold).

3. Construction of Cope. Since the finished casting is to be plastic coated, a sufficient allowance for the plastic material must be provided. This is accomplished by placing a 1/32-in. shim, cut from template paper, on the drag parting surface. The shim causes the cast model to be undersized 1/64 in. As stated previously, the airfoil sections of the pattern are quite thin and, in addition, the leading and trailing edges are nearly knifelike in configuration. To make sure that sufficient metal will be provided (when pouring the casting) to form the thin leading and trailing edges, several strips of masking tape, approximately 3/8-in. to 1/2-in. wide are secured along the leading and trailing edges of the lower half of the pattern. The tape compensates for the 1/32-in. shim by permitting an extra build-up of metal in these critical areas.

In order to accurately position and anchor the core in the sand mold, balance-seat centering pins are imbedded in the cope in addition to the regular core prints. This step is described at this point because of its direct relationship to the preparation of the cope. The installation of the centering pins is accomplished as follows:

a. A steel plate is fabricated with two holes located and centered in accordance with the centering holes drilled in the pattern.

b. Two centering pins (figure 12) are machined, drilled, and tapped, and then secured to the plate with machine screws (figure 13).

c. The centering pins, with the plate attached, are inserted and bottomed in the centering holes in the pattern (figure 14).

The pattern, with the centering pins installed, is positioned on the drag. Then the downgates and risers are installed (figure 15). Two steel rods (1/4-in.-dia), threaded at each end, are inserted (one each) in each end of the pattern in the core print area. The rods are utilized to hold the core securely in place in the cope when the mold is closed prior to pouring the casting. A flask is placed on the drag, then the cope half of the mold is rammed with CO_2 process sand.

> NOTE: Placing the centering pins in the cope is not considered mandatory. However, since the casting is poured through a sprue in the cope, the centering pins, when embedded in the cope, will resist any tendency of the core to rise when struck by the inrushing molten metal.

Upon completion of the cope, the risers, downgates, tie rods, pattern, shim, and wood gates are removed. (The balance-seat centering pins remain in the cope as shown in figure 16.) The cope and drag halves of the mold are then brush-coated with a special core wash to seal the sand pores, fill in minute depressions, and improve the finish of the casting. The core wash used for this purpose is prepared as follows:

a. Add 1/2 pint of water to 1 pint of D & S core wash, and mix thoroughly.

b. Add 1 quart of alcohol and approximately 1-1/2 quarts of zircon flour to the core wash. Then mix

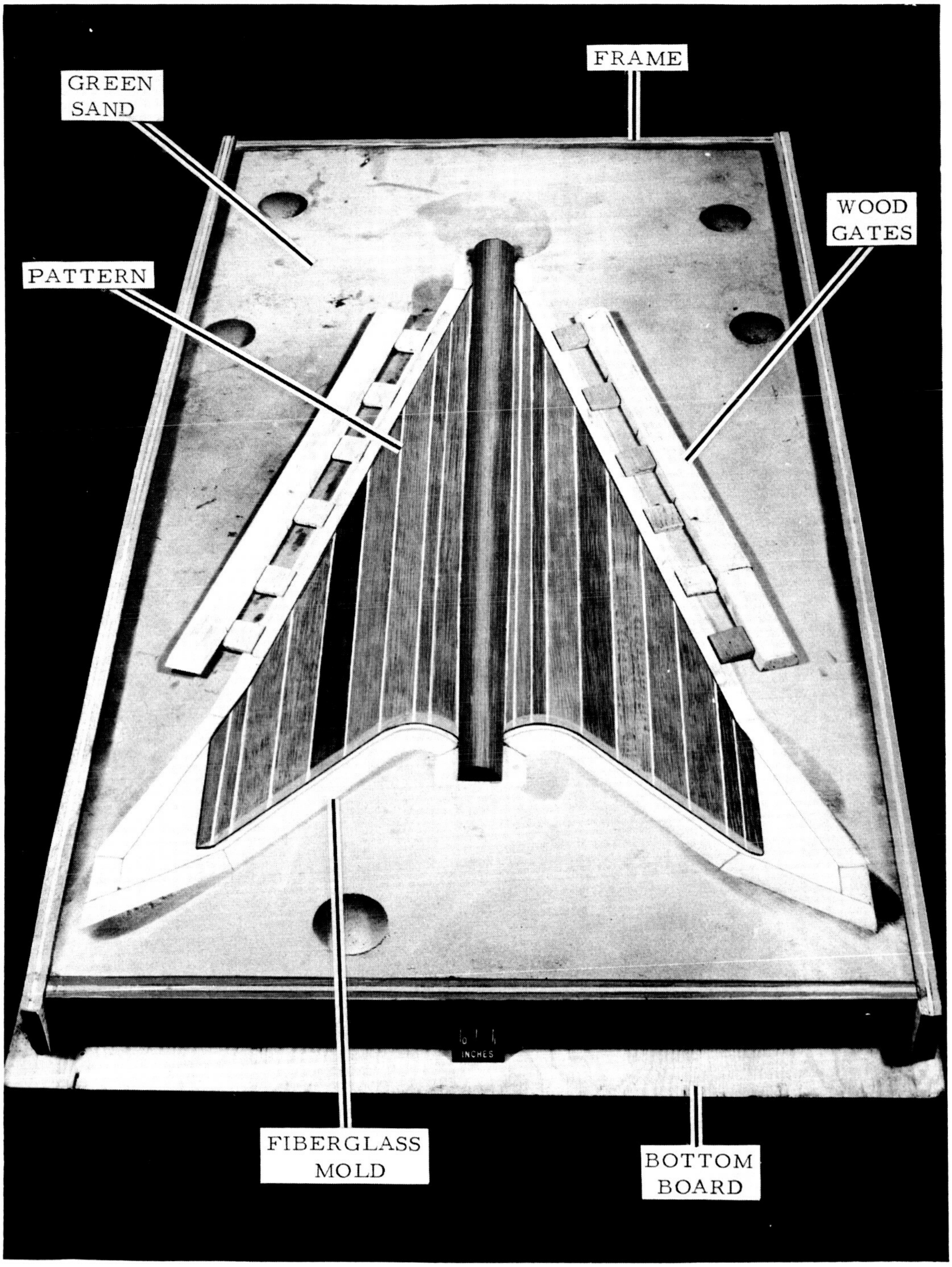


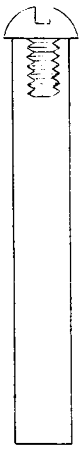
Figure 11. Preparation of False Cope

until a heavy paste (similar to putty in consistency) is formed.

c. Add a mixture of 1/2 pint of alcohol and 1/4 pint of truline binder to the paste, and then stir thoroughly until the mixture is blended.

The core wash, as prepared above, will remain in suspension better than a thinner solution. The core wash is thinned with alcohol to obtain the required quantities. When not in use, the core wash should be stored in a tightly covered container.

4. Construction of Core. With the steel arbor and vent wire securely positioned in the core box (figure 9), a centering disk is placed on one end of the arbor. The core box is then rammed with CO_2 process sand through the open end of the core box. Long cores are prepared by first ramming one half of the core box, then removing the centering disk from the opposite end and ramming the remaining half of the core. After ramming is complete, the vent wire is withdrawn and the core cured by impregnating with CO_2 gas. After curing, the core is removed from the



CENTER PIN DRILLED AND TAPPED FOR MACHINE SCREW

Figure 12. Balance-Seat Chill Centering Pins

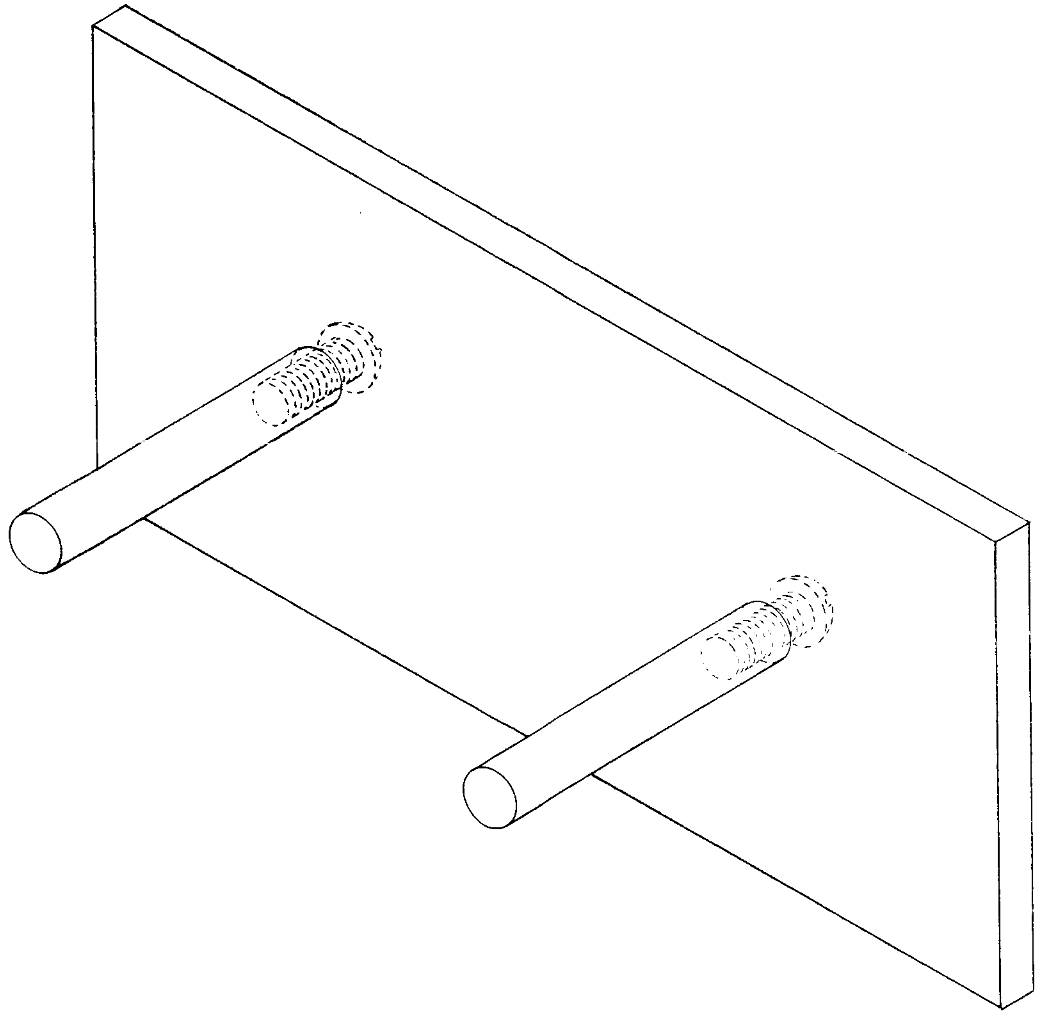
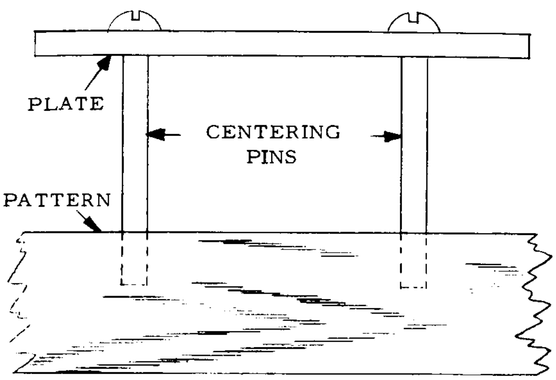


Figure 13. Balance Seat Centering-Pin Assembly



HOLES DRILLED IN PATTERN TO DEPTH EOUALLING CASTING WALL THICKNESS PLUS DEPTH OF CENTERING HOLES IN BALANCE SEAT CHILL

Figure 14. Location of Balance Seat Centering-Pins in Pattern

core box and coated with core wash. The balance seat chill pins are then inserted in the chill (figure 17).

The steel tie rods are threaded into each end of the core, then the core is carefully positioned on the centering pins as shown in figure 18. The tie rods, which extend through the cope, are then tightened (utilizing nuts and flat washers), thus holding the core securely in place. The mold is then closed and the casting poured with #225 gun metal.

POURING THE CASTING

Since the airfoil sections of the model are quite thin, it is essential that the flow of molten gun metal to those parts of the mold be assured. In addition, a good flow of metal, in sufficient quantity, must be provided if an accurate and relatively flawless balance seat is to be obtained. Therefore, the gun metal is poured at a temperature of about 2250°F, or approximately 200°F over the normal pouring temperature. The higher temperature prevents the molten metal from setting too rapidly, especially in the narrow or thin areas of the mold. This makes possible the progressive solidification of the molten gun metal in unbroken sequence from the farthest end of the casting to the point of entry. To minimize warpage, the poured casting is permitted to cool to approximately room temperature before being removed from the mold. The completed casting is cleaned in accordance with regular foundry practice.

> NOTE: At Langley, #225 gun metal is considered an ideal material for wind-tunnel models because of its versatility. Gun metal is easily worked, is readily adaptable to plasticizing, and is less prone to deflection during wind-tunnel tests. Although #225 gun metal was selected for this particular model, successful models have been produced with #17-4PH stainless steel, #335 aluminum, and magnesium.

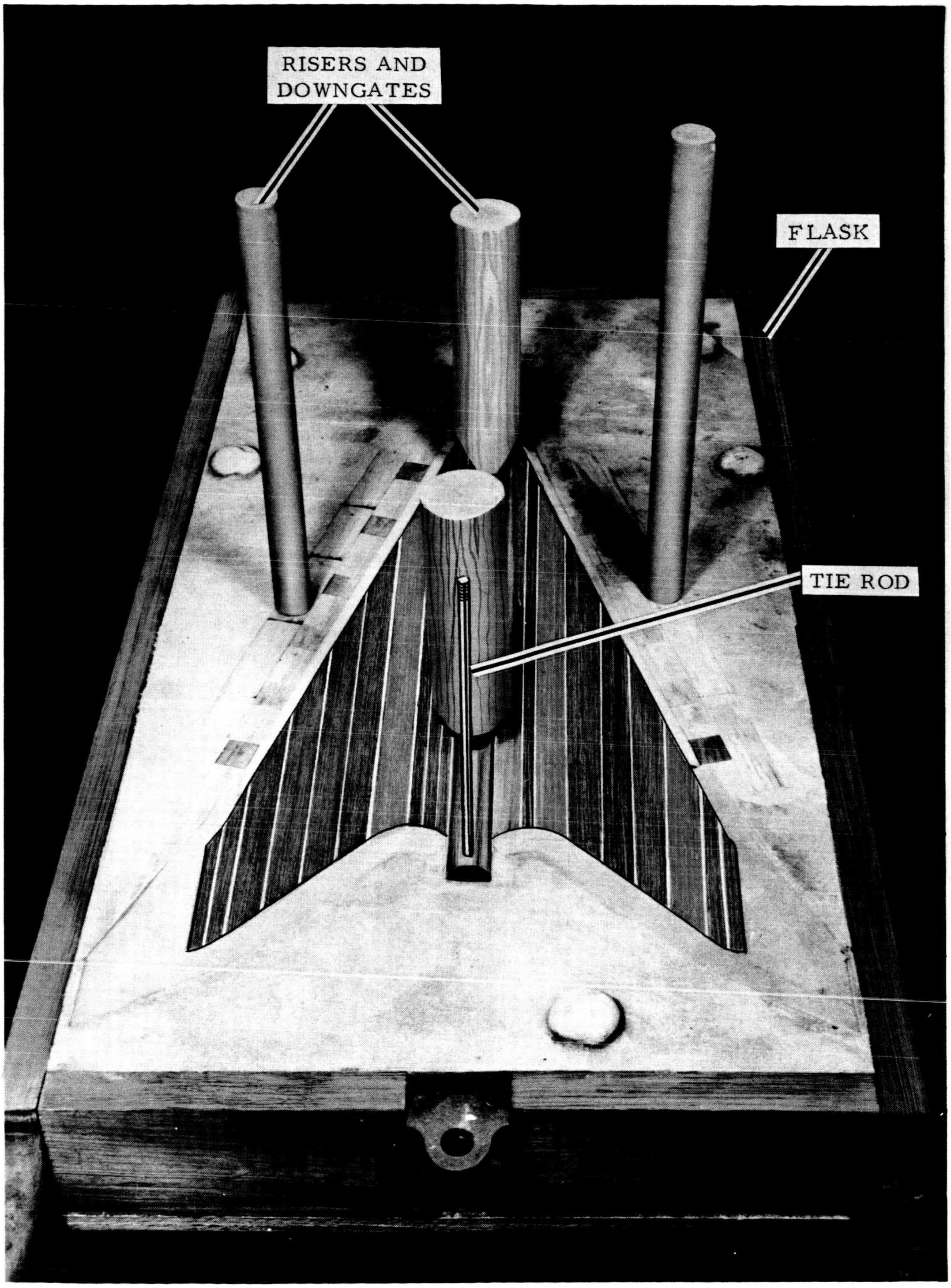


Figure 15. Preparation of Cope

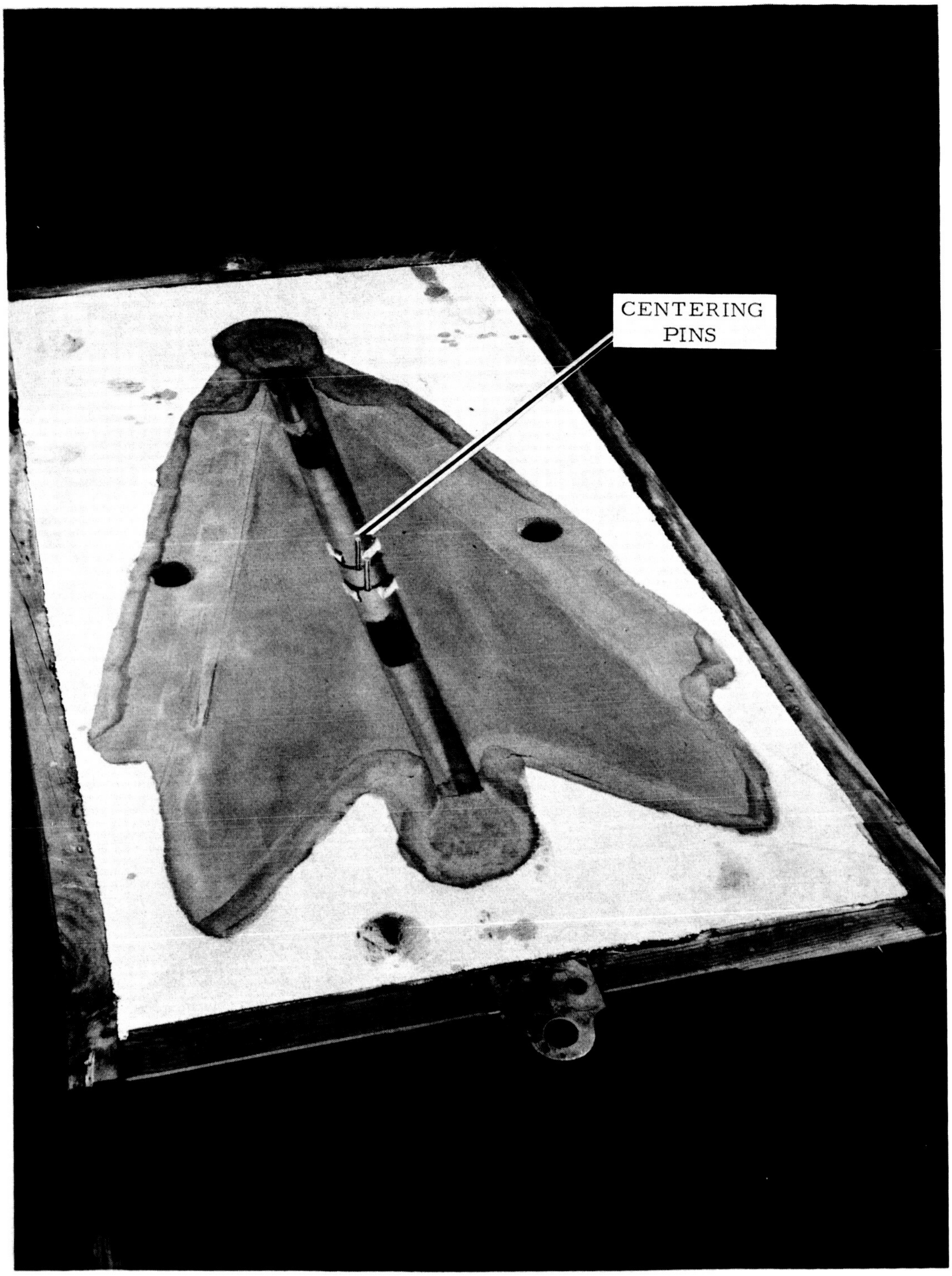


Figure 16. Location of Balance-Seat Centering Pins

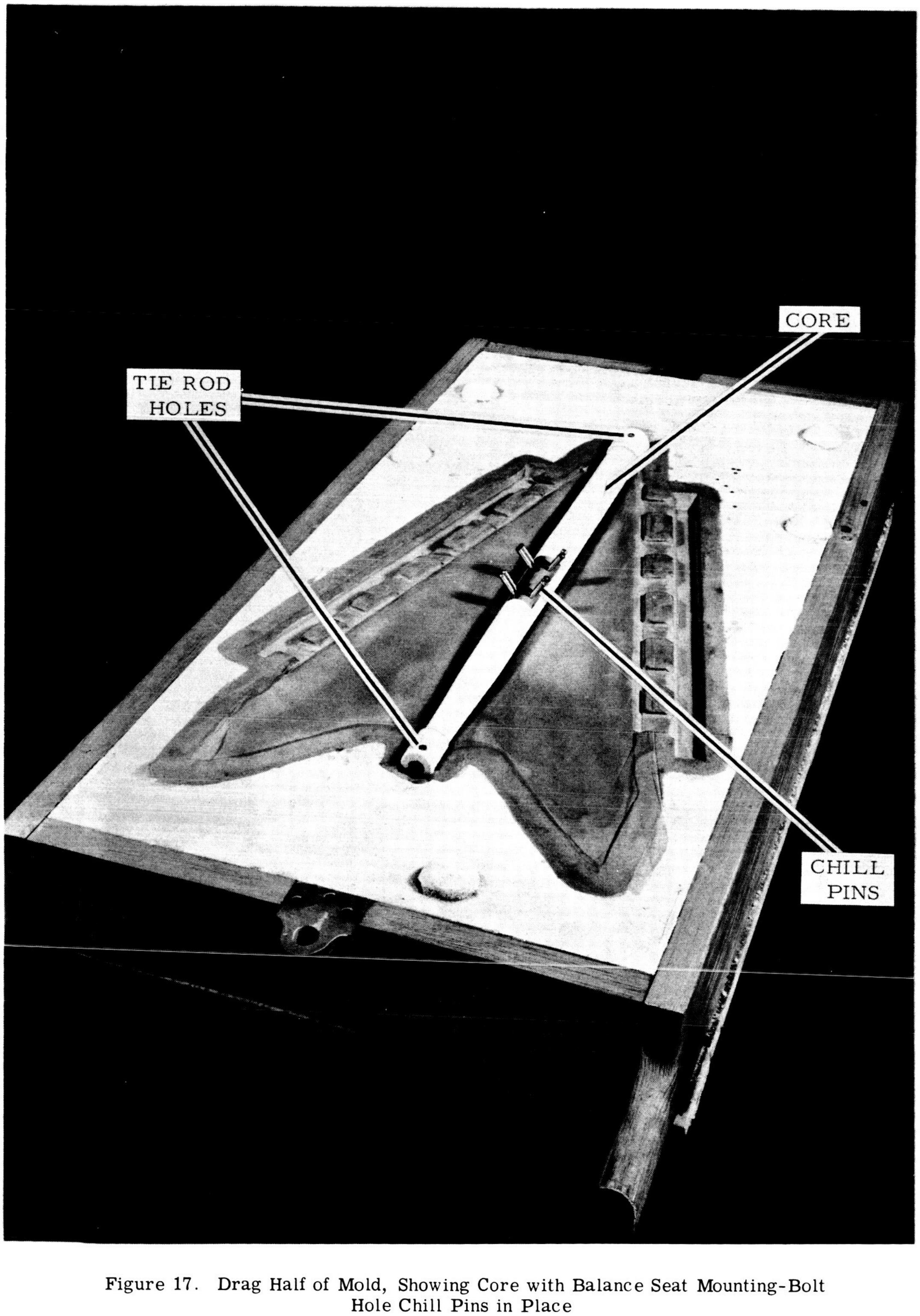


Figure 17. Drag Half of Mold, Showing Core with Balance Seat Mounting-Bolt Hole Chill Pins in Place

Figure 18. Cope Half of Mold with Core in Place

SECTION III

PLASTICIZING THE MODEL

PREPARATION OF CASTING

The completed casting is sent to the model shop for finishing prior to applying the plastic coating. The finishing procedure primarily concerns milling the plan contours of the model to the plan form, and checking the fit of the model in the fiberglass mold. This is accomplished as follows (see figure 19):

1. A plan form template is cut from aluminum or other suitable material; then the base line and all necessary stations and ordinates are laid out on the template.

2. Since the casting is to be placed directly on the plan-form template for the milling operation, the balance-seat centering pins, which are used to locate and center the core in the cope, are firmly attached in the correct position to the plan-form template. This is done to ensure accurate alignment of the casting to the plan-form template. The plan-form template is then spotted to a surface table.

3. Wood feet are prepared and glued to the lower half of the casting in true relation to the reference plane. The casting, with feet attached, is then carefully placed on the centering pins and spotted to the plan-form template.

4. Using a router with a suitable milling cutter, and utilizing the plan-form template as a guide, or fence, the airfoil edges are milled to a duplicate of the plan form.

Upon completion of the milling operation, the casting is enclosed in the fiberglass mold to check the parting (proper closing of the mold around the casting). The casting is worked, or dressed, as required to ensure closure of the mold, after which the casting is cleaned and sandblasted in preparation for the plasticizing process.

APPLICATION OF PLASTIC COATING

The application of the plastic coating to the casting is accomplished as follows:

1. The mold parting is prepared by applying a coating of wax to the mold surfaces, followed by a coating of polyvinyl parting agent (PVA).

2. Wood strips are prepared for the purpose of covering the joint at the junction of the two molds. It should be noted that although the use of the wood strips is not mandatory, their function is considered useful in that they will retard any excessive runoff of plastic at the sides of the mold. If desired, the wood strips may be grooved to provide space for runoff of the plastic.

3. Wood risers (see figure 20) are fabricated and secured to the rear end of each half of the mold.

4. The casting and both halves of the mold are then given one coat of epoxy resin, brushed on to a thickness of approximately 0.040 in. to 0.050 in. (figure 21).

5. After the epoxy resin is applied, the mold is closed. The wood strips are positioned around the mold joint, and clamps are placed in position and

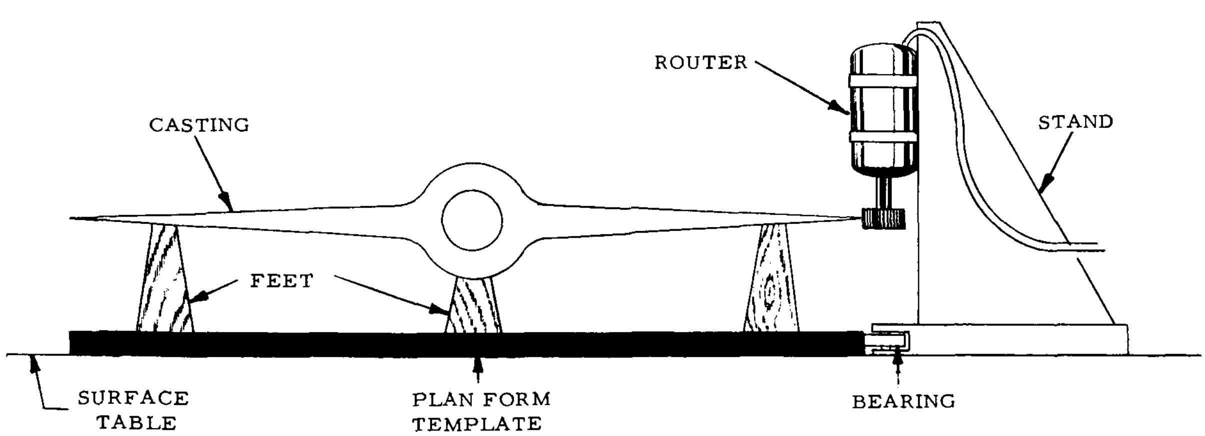


Figure 19. Milling Casting to Plan-Form Contour

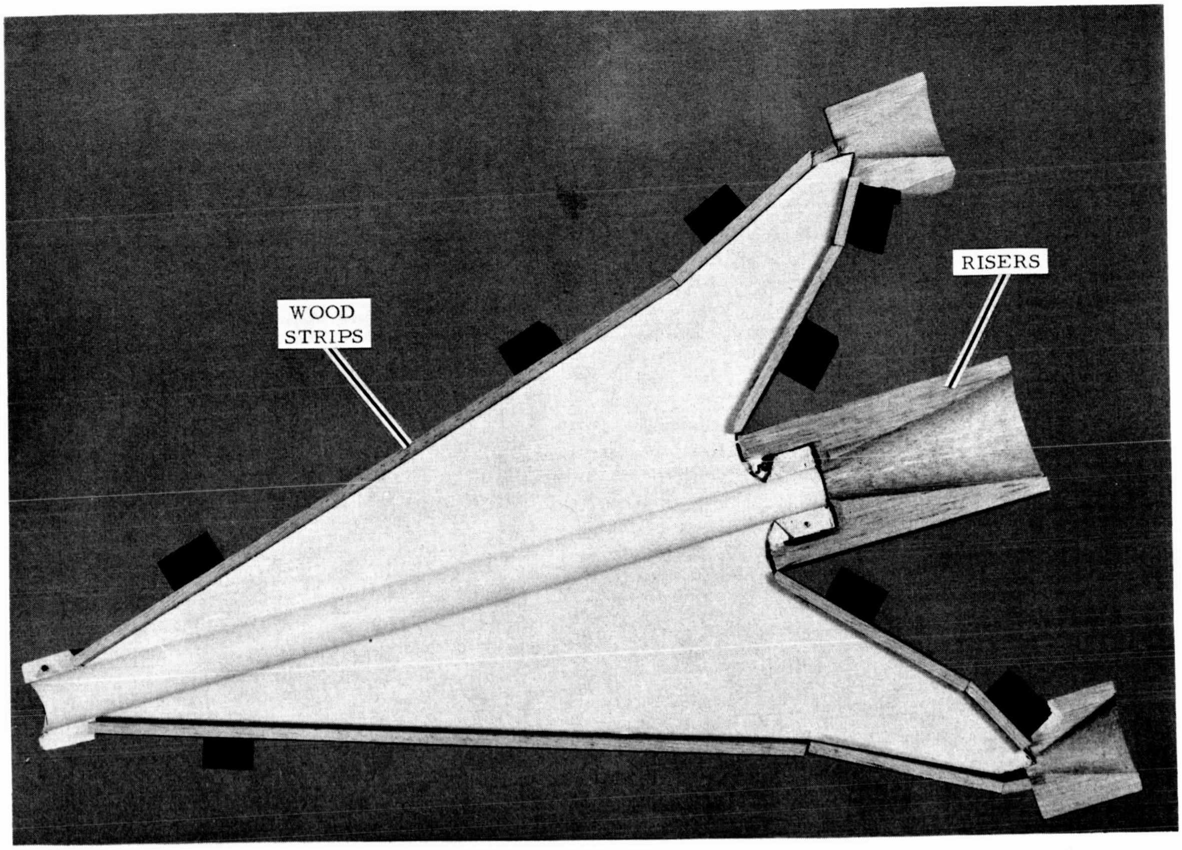


Figure 20. Location of Risers on Fiberglass Mold

securely tightened. Plaster of paris is then applied to all joints as a sealant (figure 22).

6. The assembled and clamped mold is then placed in an oven and baked or cured at 150° F for 4 hours. (Curing period varies with the type of epoxy.) During the curing period, the mold is frequently inspected and additional liquid epoxy resin added to risers as required. A slight runoff of epoxy resin is permissible since it aids in removing any entrapped air from the mold.

7. After the 4-hour curing period, the finished model (figure 23) is removed from the mold. Flash (excess plastic) is removed from the edges of the model at the parting line, and the plasticized surfaces are smoothed and polished as required.

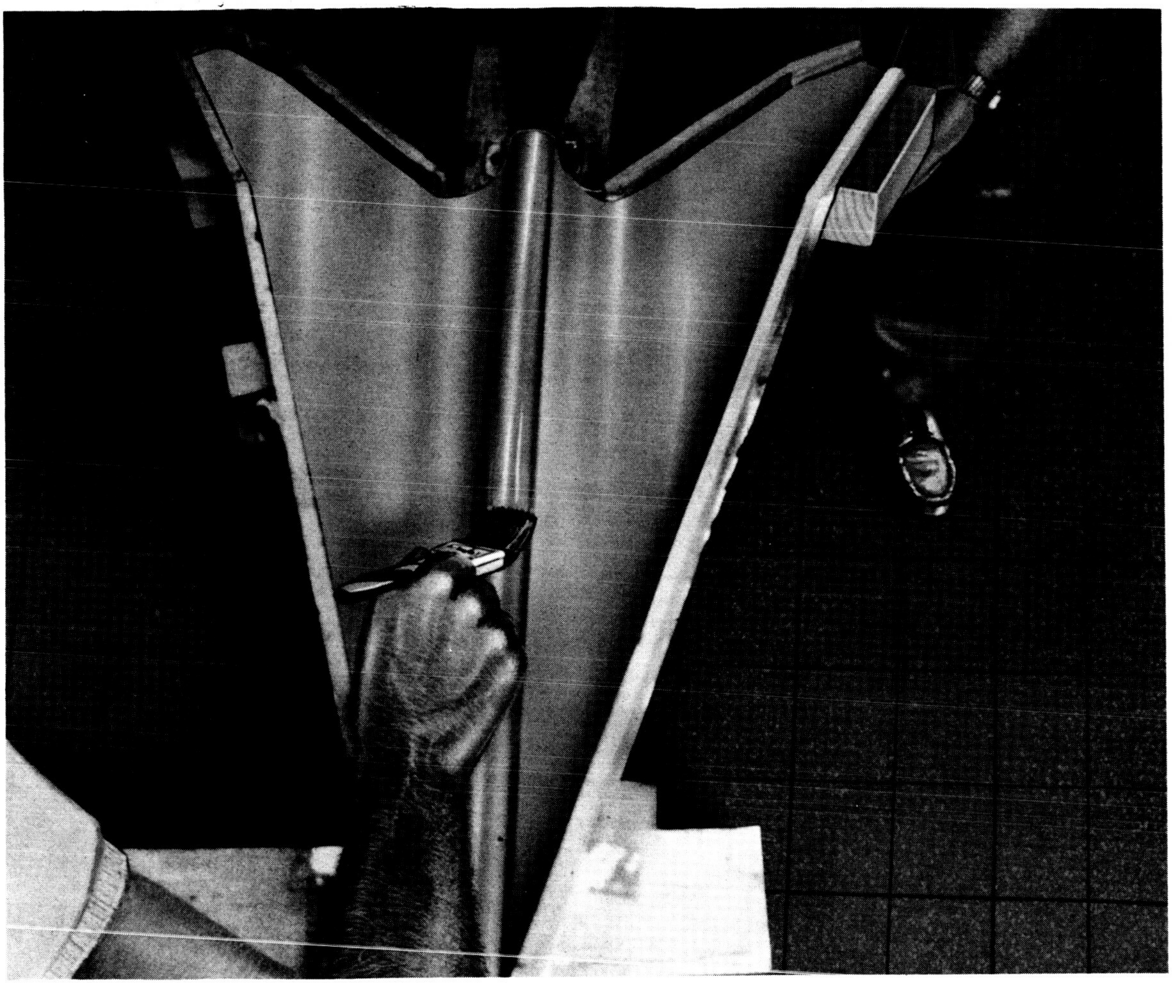


Figure 21. Applying Epoxy Resin to Casting and Fiberglass Mold

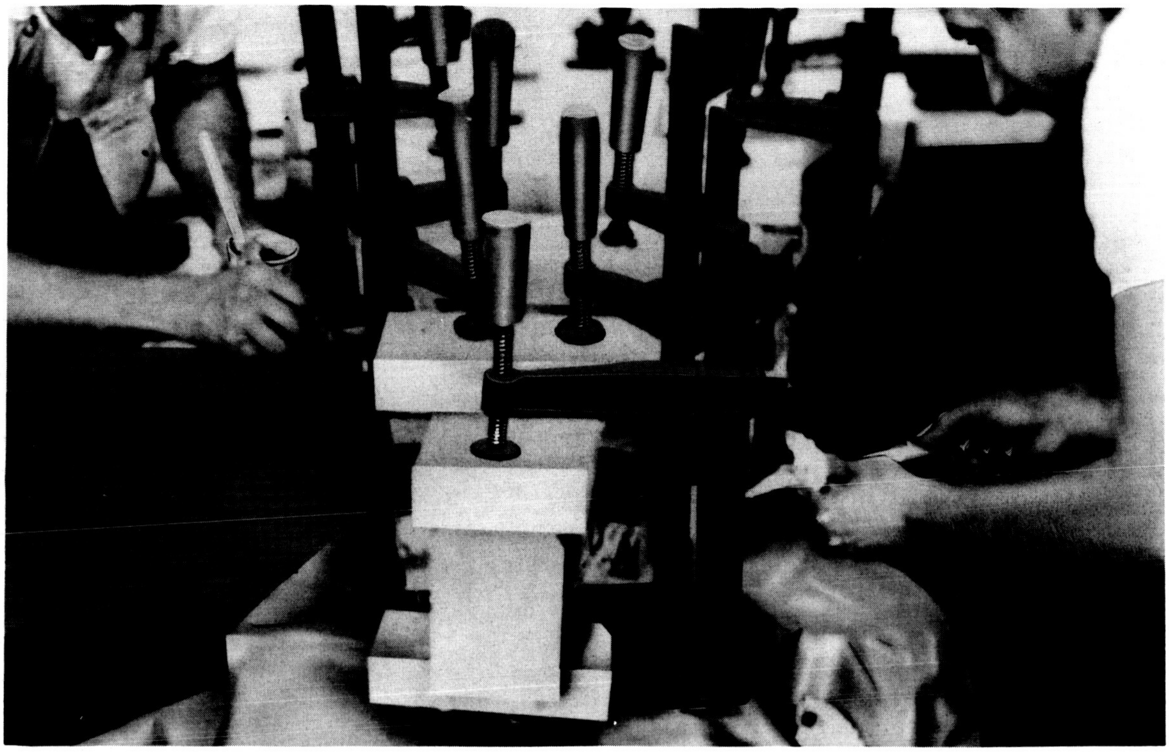


Figure 22. Applying Sealant to Fiberglass Mold

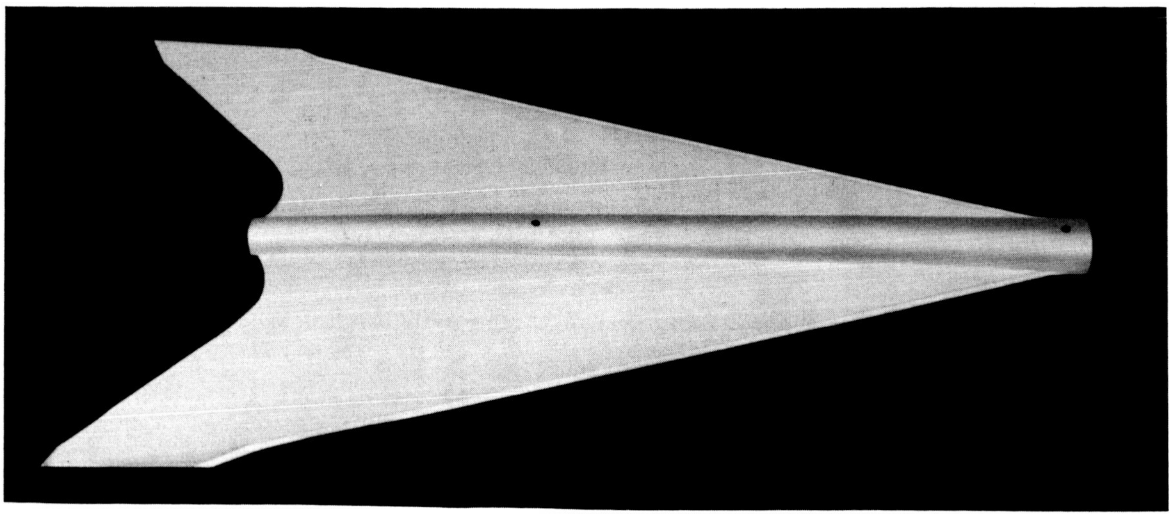


Figure 23. Completed Model

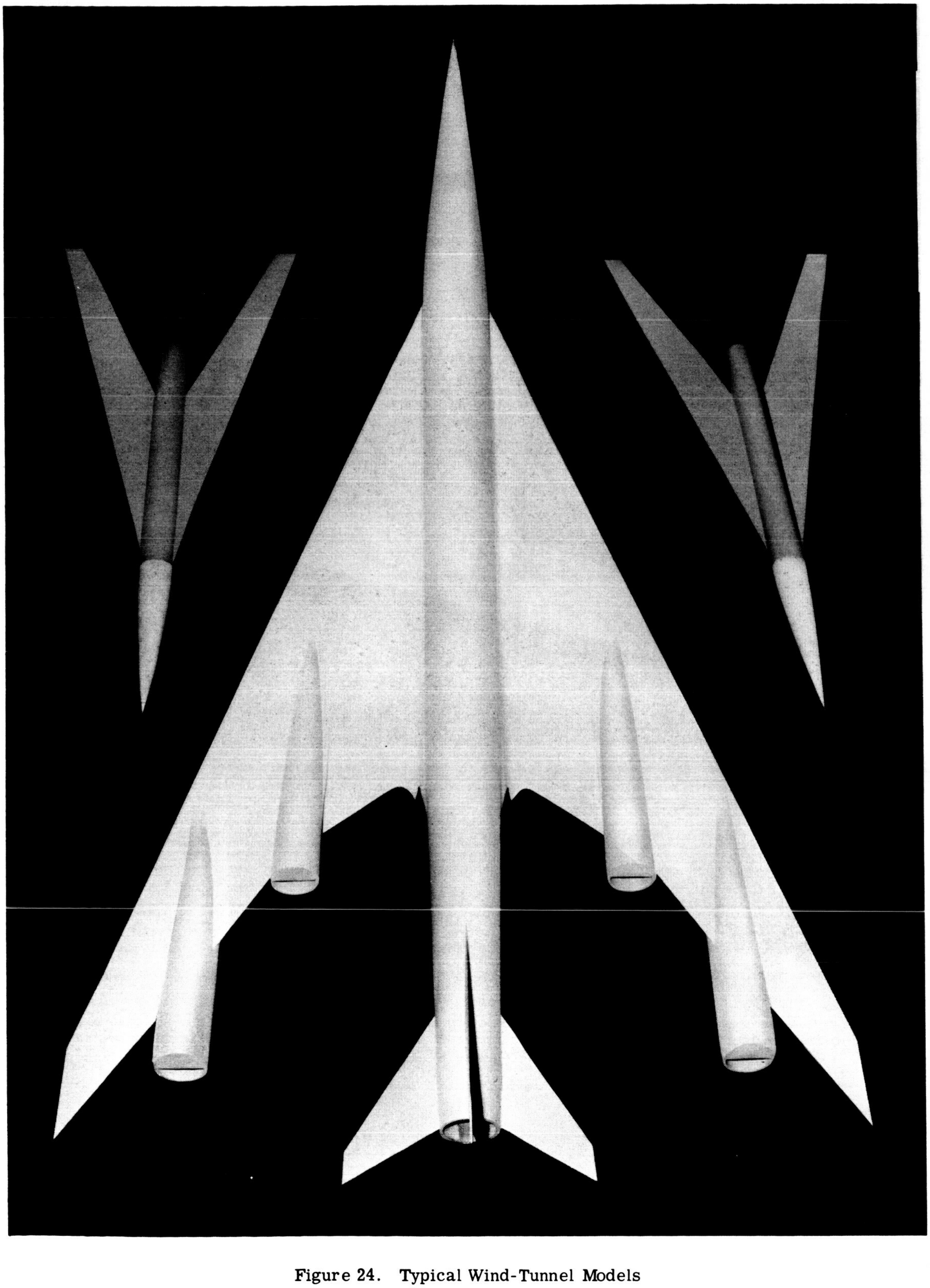


Figure 24. Typical Wind-Tunnel Models

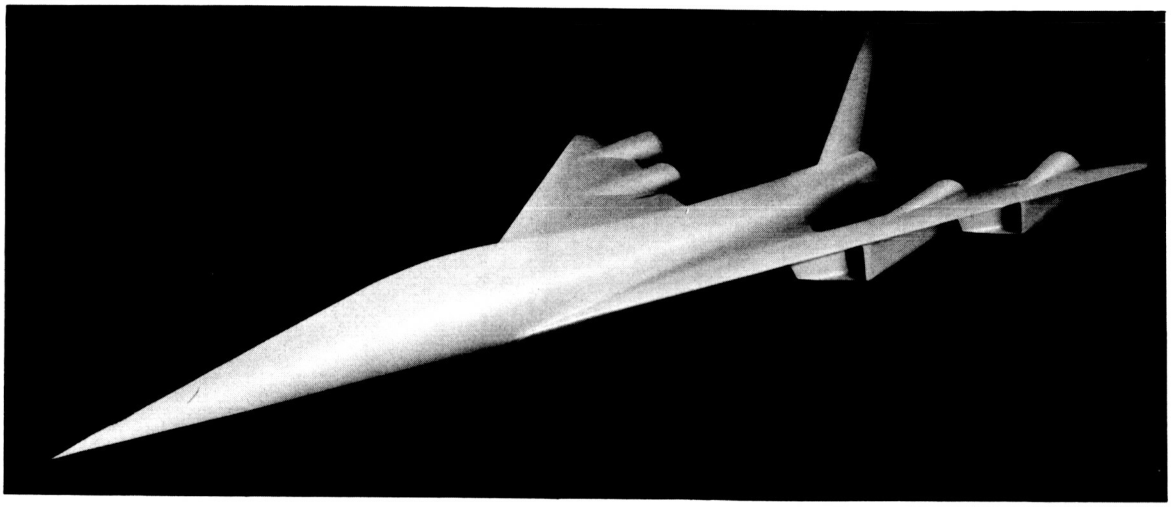


Figure 25. Typical Wind-Tunnel Models

SUMMARY

Accurate castings, of complex, thin, or odd-shaped configuration, in limited quantities, can be quickly and easily obtained by utilizing the procedures just described. The establishment of these procedures involves the adaptation and incorporation of readily available materials, and the modification of regular patternmaking and foundry practices. Therefore, the various steps and techniques should not be considered as inflexible; they may be modified as required or desired. The use of uncommon tools, intricate jigs, or other "special" fabrication devices is not required.

Although the physical contours of the model portrayed in this publication are of relatively simple design, numerous models of varying complexity (including those with pods and flow-through nacelles) have been produced at Langley (see figures 24 and 25). In addition to aircraft models, various design configurations of space vehicles capable of re-entry have been cast. The models were successful, not only in their ultimate use by research personnel, but also from the standpoint of savings in cost and production time.

As stated previously, the fact that the procedures contained in this publication were developed for the expeditious production of wind-tunnel models does not prevent their application or adaptation, either in whole or in part, to other projects by industry.

NASA-Langley, 1966